Seasonal Distribution of *Anthocoris* spp. and *Deraeocoris brevis* (Heteroptera: Anthocoridae, Miridae) in Orchard and Non-Orchard Habitats of Central Washington

DAVID R. HORTON AND TAMERA M. LEWIS

USDA–ARS, 5230 Konnowac Pass Road, Wapato, WA 98951

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ABSTRACT Occurrence of *Anthocoris tomentosus* Péricart, *A. antevolens* White, *A. whitei* Reuter, and *Deraeocoris brevis* (Uhler) in non-orchard habitats is described for areas adjacent to the pear growing regions of Yakima, WA. The four species were found on a number of tree and shrub species, especially willow, cottonwood, oak, alder, aspen, poplar, and bitterbrush. The four predators differed in degree of specialization. *A. whitei* was found almost exclusively on antelope bitterbrush (*Purshia tridentata* Pursh), apparently in close association with an unidentified psyllid. The other two anthocorids were more generalized, but differed in occurrence on some tree species. Adult and immature *A. antevolens* were common on oak, cottonwood, and poplar. Conversely, *A. tomentosus* was comparatively uncommon on these species, but was more abundant than *A. antevolens* on the neighboring willows; immatures of *A. tomentosus* were never recovered from oak. Adult and immature *D. brevis* were collected from several species not shown to support populations of *Anthocoris* spp., suggesting that the mirid is more of a generalist than the anthocorids. *Anthocoris* spp. were rare in apple orchards, whereas *D. brevis* was common there. *A. tomentosus* and *A. antevolens* showed distinct seasonal changes in plant use. Both species congregated on willow catkins beginning in March, but began to appear on summer hosts (oak, cottonwood, alder, aspen, poplar) in May and June. Some of the movement from willow may have been a result of the disappearance of a univoltine psyllid from this host plant. Traps composed of corrugated cardboard were placed at different sites to collect overwintering predators. *A. antevolens* and *D. brevis* were more broadly distributed among plant species than *A. tomentosus* or *A. whitei* (the latter restricted to pear and bitterbrush). *A. antevolens* was very abundant in traps collected from poplar and cottonwood, apparently because both tree species are important sources of late-summer prey for this predator. Other miscellaneous Anthocoridae and *Deraeocoris* spp. were collected while sampling, and lists of these species are provided. *Orius tristicolor* (White) was common at several sites, and was easily the most abundant anthocorid in overwintering traps at one intensively sampled orchard. This species was particularly abundant in traps placed in peach trees. Overwintering sex ratios of *D. brevis*, *Anthocoris* spp., and *O. tristicolor* were moderately to strongly female-biased.

KEY WORDS Heteroptera, Anthocoridae, Miridae, *Orius*, overwintering, pear psylla

PREDATORY HETEROPTERA ARE important natural enemies in many agricultural systems (Coll and Ruberson 1998). Insects in the family Anthocoridae and certain species in the family Miridae are often particularly effective against small, soft-bodied arthropods such as aphids, psyllids, thrips, and mites (Westigard 1973, Herard 1986, Hodgson and Aveling 1988, Lattin 1999). In the Pacific Northwest, species of *Anthocoris* (Anthocoridae) and *Deraeocoris* [Miridae; particularly *D. brevis* (Uhler)] may be effective biological control agents for pear psylla, *Cacopsylla pyricola* (Foerster), if the predators are present in pear orchards at the right time of the year (Madsen 1961, Madsen et al. 1963, Madsen and Wong 1964, Westigard et al. 1968, Fields and Beirne 1973). However, their presence in pear orchards is highly irregular year-to-year apparently caused in part by the availability of suitable habitats and prey outside of the orchard ecosystem.

The primary objective of this study was to monitor the use of orchard and non-orchard habitats by three species of *Anthocoris* (*A. tomentosus* Péricart [often referred to in the literature as *A. melanocerus;* Henry 1988], *A. antevolens* White, and *A. whitei* Reuter), and by the predatory mirid *D. brevis*. All species have been reported to occur in pear orchards located in the western United States; *A. antevolens*, *A. tomentosus*, and *D. brevis* may be especially effective predators of pear psylla (Madsen 1961, Madsen et al. 1963, Westigard et al. 1968). Sampling efforts in this study focused on habitats that occur in the vicinity of the pear and apple growing regions near Yakima, WA, to determine whether these alternative habitats are a source of predators moving into orchard habitats. Here, we summarize the results of 2 yr of sampling. During the first year we completed a fairly broad screening of different plant species to determine whether certain species are more important than others as sources of *D. brevis*

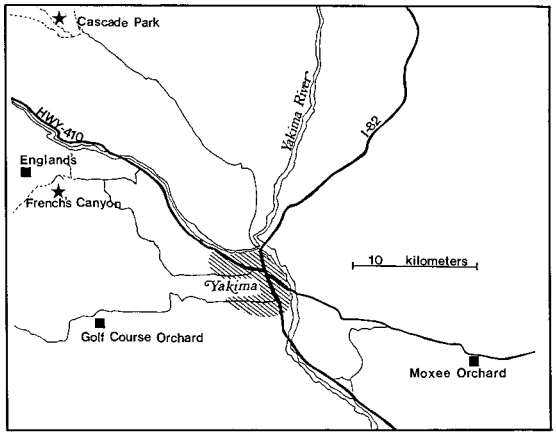

Fig. 1. Location of non-orchard habitats (Cascade Park and French's Canyon; designated by stars) monitored for *Anthocoris* spp. and *D. brevis*. Three orchards (England's, golf course, Moxee) designated by squares. Bitterbrush and poplar were also sampled at the England's orchard site.

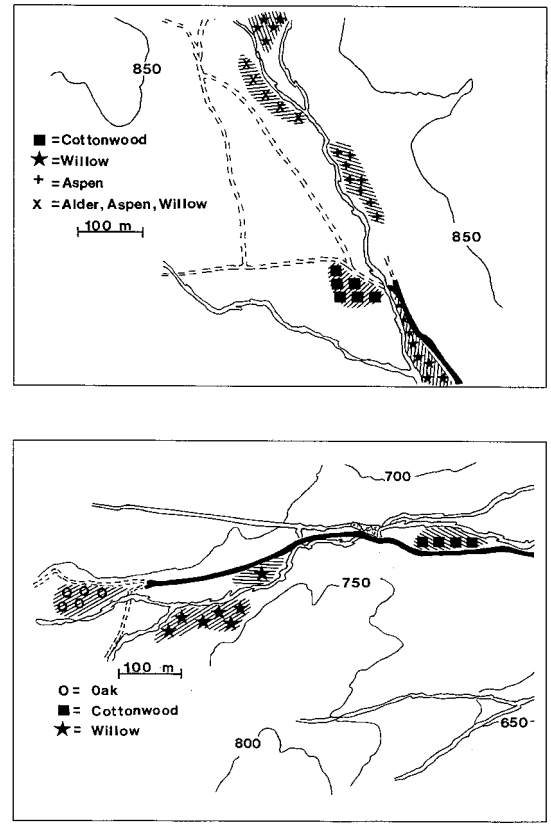

Fig. 2. Depiction of Cascade Park (upper panel) and French's Canyon (lower panel) sites used in the 1996 and 1997 sampling studies. Roads indicated by thick black lines and by dashed lines (gravel). Location of intensively sampled (1997 study) patches of willow, oak, cottonwood, aspen, and alder shown as hatched areas adjacent to streams. Approximate sample sizes for intensively monitored species: willow, 20–30 shrubby stands at each site (individual stands occasionally reaching eight m in diameter); cottonwood, 10–12 trees at Cascade Park and five trees at French's Canyon; oak, 20–30 trees; aspen, 15–20 small, shrubby trees intermixed with willow; alder, 15–20 small, shrubby trees intermixed with willow.

and *Anthocoris* spp. In the second year, we concentrated monitoring efforts on a few select tree and shrub species shown during the 1996 study to be important host plants, and described seasonal use of these plants by three species of *Anthocoris*. Certain species of *Anthocoris* show seasonal changes in their use of different plant species, apparently in response to availability of prey (Anderson 1962b, Shimizu 1967, Hill 1978). Furthermore, although it is known that *A. tomentosus* and *A. antevolens* overlap extensively in geographical range and in use of certain plant species (Anderson 1962a), it is not clear whether the two species are completely similar in prey and host plant preferences.

The second objective of this study was to determine the importance of different plant species as overwintering sites, and to monitor sex ratios of overwintering adults. Finally, we encountered, at intervals, species of *Deraeocoris* or Anthocoridae that rarely or never occur in orchard habitats. Little is known about the biology of several of these species, so we use this opportunity to present some brief observations on their occurrence in our samples.

Materials and Methods

Study Sites. Several areas in or adjacent to the pear growing regions of Yakima, WA, were monitored (Fig. 1). Non-orchard habitats included three areas west of Yakima and Tieton (latitude 46° 30′ N). The three areas fall within the Ponderosa pine (*Pinus ponderosa* Douglas)–sagebrush (*Artemisia tridentata* Nuttall) ecosystem, composed of a mix of woody and herbaceous plant species. The French's canyon and Cascade Park locations both have a strong riparian component and are dominated by a mix of deciduous and evergreen trees. Important tree and shrub species in the two areas include a shrubby willow (*Salix* spp.; apparently largely *S. scouleriana* Barratt), black cottonwood (*Populus trichocarpa* Torrey & Gray), Oregon oak (*Quercus garryana* Douglas), and Ponderosa pine at French's canyon, and willow, cottonwood, alder (*Alnus* sp.), quaking aspen (*Populus tremuloides* Michaux), and Ponderosa pine at Cascade Park. The areas sampled comprised a 500–700 by 50–80 m wide band of habitat at each site extending along the local stream system (Fig. 2).

The third non-orchard site is an area of native rangeland occurring adjacent to England's orchard (Fig. 1). The site contains a large stand (several hundred plants) of antelope bitterbrush [*Purshia tridentata* (Pursh)], extending 10–200 m from the orchard. A 40-m row of Lombardy poplar (*Populus nigra* L.) windbreak occurs between the bitterbrush and the orchard, and was also sampled. Bitterbrush was shown

Table 1. Tree and shrub genera monitored at French's Canyon, Cascade Park, and England's orchard sites during general plant screening study (1996)

Salicaceae: *Salix* (willow), *Populus* (aspen, cottonwood, poplar)
Betulaceae: *Alnus* (alder)
Fagaceae: *Quercus* (oak)
Aceraceae: *Acer* (maple)
Rosaceae: *Purshia* (bitterbrush), *Aruncus* (goatsbeard), *Rosa* (rose), *Rubus* (blackberry), *Holodiscus* (oceanspray), *Crataegus* (hawthorn), *Amelanchier* (serviceberry), *Prunus* (chokecherry)
Grossulariaceae: *Ribes* (currant)
Hydrangeaceae: *Philadelphus* (mock orange)
Cornaceae: *Cornus* (dogwood)
Caprifoliaceae: *Sambucus* (elderberry), *Symphoricarpos* (snowberry)
Compositae: *Chrysothamnus* (rabbit-brush), *Artemisia* (sage-brush)
Leguminosae: *Lupinus* (lupine)
Pinaceae: *Pinus* (ponderosa pine)

to be an important habitat for *A. whitei*, and the windbreak was found to be an important source of late-season prey to *A. antevolens* (see *Results*). Three orchards were also monitored: Moxee, the golf course, and England's orchard (Fig. 1).

Preliminary Assessment of Host Plant Use by *Anthocoris* spp. and *D. brevis*. Our initial sampling efforts were done in 1996 with aims to identify the more important plant taxa for these predators; this preliminary effort allowed more intensive sampling of a subset of plant species in 1997 (see below). Sampling activities in 1996 focused primarily on the common tree and shrub species (Table 1) occurring at Cascade Park, French's Canyon, and in the area adjacent to England's orchard. The plant taxa that were monitored (Table 1) differed substantially in relative abundances within and between sites. The most abundant woody plants at these sites are members of *Salix, Populus, Alnus, Quercus* (French's Canyon only), *Rosa, Rubus,* and *Pinus.* Several of the more common herbaceous species were also monitored, including members of the Compositae (yarrow, thistles, knapweed), Cruciferae (mustards), Scrophulariaceae (mullein, penstemon), Leguminosae (clovers), Umbelliferae (parsley, wild carrot), Polygonaceae (docks, buckwheat), Urticaceae (nettle), Labiatae (mint), and miscellaneous grasses and sedges. Most of the collecting was done using beat trays (46 by 46 cm) and aspirators. Some herbaceous species were sampled using sweep nets. The Cascade Park and French's Canyon sites were sampled 2–3 times per month between March and September 1996. At the England's site, where we sampled bitterbrush and poplar, samples were taken more irregularly and we monitored the site both in 1996 and 1997: bitterbrush (seven dates between March and September in 1996; eight dates between March and July in 1997); poplar (four dates between June and September in 1996; five dates between April and June in 1997). In 1996, we also sampled three orchards at approximately monthly intervals: Moxee (pear, apple, plum, peach, nectarine); England's orchard (pear); golf course (pear).

Because of the large number of plant species to be monitored and because species differed in relative abundance and in structure, it was impossible to produce any sort of standardized sampling method that would allow statistical comparisons of insect densities among plant species. Instead, for this general screening study, our objectives were to compare very broadly the several predator species in occurrence on the more common plant species in the study areas. At each of the three non-orchard sites (Figs. 1–2), we began sampling at one end of the site and walked to the opposite end of the site, while sampling the different plant species as they were encountered. We attempted to take enough samples for a plant species that we were comfortable in inferring presence or absence of the different predators. Plant species that were often heavily infested with the predators (e.g., willow) required but a few trays to show presence of the predators, whereas less favored or less abundant plant species required more intensive sampling. Some species (e.g., hawthorn, represented by a single stand) were very uncommon, and the entire population was sampled; other species (e.g., oak at French's canyon) were abundant, and a portion of the population was sampled. At the three orchards, we sampled 20–30 pear trees on each date and a lesser number of trees for each of the other fruit species. At all sites, predators were either identified in the field or were aspirated from trays, taken to the laboratory, and identified. Immature *D. brevis* and *Anthocoris* spp. were noted when present; immatures of the latter were not identified to species in this portion of the study. We emphasize that this initial study was not done to obtain an exhaustive list of plant species used by each predator. However, because every tray or sweep net sample was examined for each predator species, this study did allow us to make nonstatistical inferences about diet breadth in the different species of predators.

Seasonal Use of Common Plant Species by *Anthocoris* spp. Results of the 1996 study allowed us to reduce monitoring efforts in 1997 to a few important tree and shrub species (Fig. 2). These plants were monitored intensively to assess seasonal changes in host plant use by *A. tomentosus* and *A. antevolens.* Species that were monitored included willow (both sites), oak (French's Canyon), cottonwood (both sites), alder (Cascade Park), and aspen (Cascade Park). Stands or patches of the different species grow within 100 m of one another, occasionally in mixed-species stands (Fig. 2); thus, we assume that predators at a given site had access to each plant species. Population sizes for the different host species are summarized in the caption of Fig. 2. Both sites were sampled intensively two to three times per month between March and September 1997 using beat trays. We intentionally monitored the same stands of plants on each sampling date, thus sampling intensity for each plant species was relatively constant throughout the study. Additionally, enough data were collected in the 1996 samples taken from poplar, bitterbrush, and pear (see previous section) to allow some inferences to be made about predator phenology on these plants. Some supplemental sampling information was obtained as time allowed in 1997 for poplar and bitter-

brush, and these phenology data will also be included here.

Comparative Distribution of *A. tomentosus* and *A. antevolens* on Important Host Plant Species. We compared densities of *A. tomentosus* and *A. antevolens* on willow, aspen, cottonwood, alder, and oak at the French's Canyon and Cascade Park sites (Fig. 2). Adults of these species were aspirated from beat trays, taken to the laboratory, and identified to species. We also collected nymphs of *Anthocoris* spp. from these five host plants, and took them to the laboratory for rearing. Nymphs were allowed to complete development by feeding them pear psylla. At eclosion, adults were identified to species. Sample sizes are provided in the *Results.*

Overwintering in Different Habitats. Cardboard bands and bundles (Fye 1985) were placed in the field during fall of 1995–1997 to provide overwintering sites for predators. Bands (8 cm wide) were stapled at various heights around the trunks or limbs of trees. For shrubbier species of plants such as willow and bitterbrush, we used strong twine to tie cardboard bundles to stems and limbs (bundles were 15 by 12 by 8 cm). Insects readily entered gaps in the corrugation of both types of traps. Bands and bundles were placed in the field in August or September of each year, collected during the winter, and taken to the laboratory where the traps were taken apart. All Anthocoridae and *Deraeocoris* spp. were identified, counted, and sexed. In 1995, traps were placed only in the orchards located at Moxee (Fig. 1). In 1996 and 1997, traps were put in both orchard and non-orchard habitats and in all sites (Figs. 1–2). As in the 1996 general screening study, sampling protocols and intensities were not necessarily similar among plant species. Thus, plants that grew as shrubs in large patches (e.g., *Salix*) may have had up to a dozen bundles placed within a single large patch. Trees (e.g., oak, cottonwood, tree fruit species), conversely, each received a single band stapled around the trunk, with perhaps an additional band stapled around a lower limb. Exact sample sizes (bands or bundles per plant species) are provided in the *Results.*

Miscellaneous Anthocoridae and *Deraeocoris* spp. Collected. For all sampling methods, we recorded the presence of other Anthocoridae and species of *Deraeocoris* other than *D. brevis.* As noted earlier, little is known about several of these taxa, and we use this opportunity to present some of our observations.

Voucher Specimens. Voucher specimens of *A. tomentosus, A. antevolens, A. whitei, D. brevis,* and other of the more common Anthocoridae were deposited in the museum at Washington State University, Pullman. Less common species were placed in the personal collection of the junior author (details in *Results*).

Results

Preliminary Assessment of Host Plant Use by *Anthocoris* spp. and *D. brevis*. Late winter and early spring (March–April) populations of *A. tomentosus* and *A. antevolens* were found primarily on willow, with occasional insects of both species collected from pear

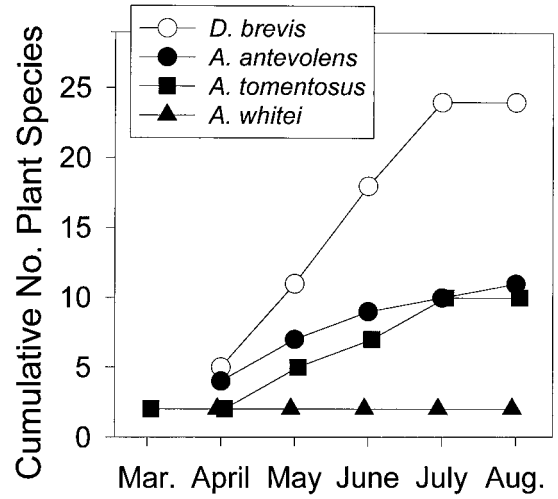

Fig. 3. Cumulative number of plant species from which *A. tomentosus, A. antevolens, A. whitei,* and *D. brevis* were collected in the 1996 general screening study. Not meant to be comprehensive depiction of host plant breadth.

(Fig. 3). Both species began appearing on other plant species beginning in May, particularly on oak, cottonwood, and alder. *D. brevis* was recorded from more species of plants than the two anthocorids (Fig. 3), suggesting that this species is a more generalized predator than *A. tomentosus* or *A. antevolens. A. whitei* was collected from two species only, bitterbrush and, much more rarely, pear. Note that Fig. 3 is not meant to be a comprehensive depiction of total host plant range for these three species; rather, the figure should be viewed as a means of showing seasonal patterns in use of host plants and for showing broad differences among the four predators. One noticeable and important difference between *D. brevis* and the anthocorids was that *D. brevis* was often abundant in apple orchards, whereas the anthocorids were uncommon in that type of orchard.

Immature *Anthocoris* spp. were recorded from 13 species of woody plants: pear, willow, alder, cottonwood, oak, aspen, poplar, bitterbrush, hawthorn, rose, chokecherry, snowberry, and squaw currant. We also recorded a few nymphs from nettle (*Urtica* sp.) located immediately beneath a willow heavily populated with *Anthocoris* spp. *Anthocoris* nymphs on bitterbrush at the England's site appeared to be entirely *A. whitei* (unpublished data), whereas those collected from poplar were entirely *A. antevolens* (unpublished data). Immature *D. brevis* were collected from most of the species from which immature *Anthocoris* spp. were collected (excluding snowberry, nettle, and squaw currant), but were also collected from several species of trees or shrubs from which both adult and immature *Anthocoris* spp. were rarely or never collected (including apple, sagebrush, and ponderosa pine; densities of *D. brevis* on apple were occasionally very high). Other plants supporting immature *D. brevis* included peach, nectarine, plum, and mock orange.

Table 2. Presence of *Anthocoris* spp. on various tree or shrub species at different times of the year

Plant species (site)	Month of Samples							*Anthocoris* adults noted
	March	April	May	June	July	August	Sept	
Species sampled 2-3 times/month (1997)								
Willow (FC, CP)	X	XX	XX	XX	XX	XX	XX	*A.t., A.a.*
Oak (FC)	00	00	X	XX	XX	XX	X	*A.t., A.a.*
Cottonwood (FC, CP)	00	00	X	XX	XX	XX	XX	*A.t., A.a.*
Alder (CP)	ND	00	XX	XX	X	00	00	*A.t., A.a.*
Aspen (CP)	ND	00	00	XX	XX	XX	XX	*A.t., A.a.*
Species sampled at irregular intervals (1996 and 1997)								
Pear (E, GC, M)	X	X	XX	XX	XX	XX	XX	*A.t., A.a., A.w.*
Poplar (E)	ND	00	X	X	00	XX	X	*A.a.*[a]
Bitterbrush (E)	X	ND	XX	XX	XX	XX	XX	*A.t., A.w.*[b]

X, adults present; XX, adults and immatures present; 00, plant was sampled but *Anthocoris* spp. not present; ND, plant species was not sampled that month because of time constraints or because snow prevented access to the site (March 1997, Cascade Park). FC, French's Canyon; CP, Cascade Park; E, England's orchard and adjacent habitat; GC, golf course orchard; M, Moxee orchard. *A.t., A. tomentosus; A.a., A. antevolens; A.w., A. whitei.*

[a] *Anthocoris antevolens* reached high densities late in the season on poplar, apparently because of infestation of poplar by a gall-producing aphid.

[b] Bitterbrush appears to be almost exclusive source of *A. whitei* in the sampling area.

Seasonal Use of Common Plant Species by *Anthocoris* spp. Regular sampling of a specific set of plant species during 1997 was used to determine seasonal changes in host plant use by *Anthocoris* spp. (Table 2). As described in the previous section, willow and (to a lesser extent) pear acted as hosts in early spring. Eggs of *Anthocoris* spp. began to appear on catkins and developing leaves of willow in April, and nymphs began to appear during late April and early May (unpublished data). The earliest collected nymphs from willow were composed primarily of *A. tomentosus* (>80%), although *A. antevolens* at the French's Canyon site became more abundant in later months (see below). On pear, nymphs were first seen beginning in early May. *A. whitei* was common on bitterbrush during most of the sampling period; nymphs were seen beginning in May (Table 2). An unidentified, reddish psyllid was present all year on bitterbrush and apparently was an important prey for this predator.

Anthocoris spp. began to appear on other tree and shrub species in May (Table 2; see also Fig. 3), coinciding with the appearance of soft-bodied prey such as aphids and psyllids on these summer host plants and the disappearance of the univoltine psyllid from willow. Of these intensively sampled plants, willow, oak, cottonwood, alder, and bitterbrush were the more

Table 3. Percentage of adult *Anthocoris* composed of *A. tomentosus* on various tree species at French's Canyon and Cascade Park sites

Plant species	Collecting period (no. dates sampled)	No. of specimens	% *A. tomentosus*[a]
French's Canyon			
Willow	Mar.–May 1996 (10)	152	80.3
Willow	Mar.–May 1997 (10)	34	100.0
Willow	June–Sept. 1996 (10)	36	77.8
Willow	June–Sept. 1997 (10)	135	65.9
Willow totals		357	76.5
Oak	June–Sept. 1996 (10)	14	0.0
Oak	June–Sept. 1997 (10)	197	2.0
Oak totals		211	1.9
Cottonwood	June–Sept. 1997 (10)	97	13.4
Cascade Park			
Willow	Mar.–May 1997 (3)	10	70.0
Willow	June–Sept. 1996 (7)	93	84.9
Willow	June–Sept. 1997 (8)	131	66.4
Willow totals		234	73.9
Cottonwood	June–Sept. 1996 (7)	56	26.8
Cottonwood	June–Sept. 1997 (8)	85	3.5
Cottonwood totals		141	12.8
Alder	June–Sept. 1997 (8)	11	54.5
Aspen	June–Sept. 1997 (8)	47	53.2

[a] No *A. whitei* were collected from these tree species; thus, percentage of sample composed of *A. antevolens* is equal to (100%–% *A. tomentosus*).

Table 4. Percentage of nymphal *Anthocoris* composed of *A. tomentosus* on various tree species at French's Canyon and Cascade Park sites

Plant species	Collecting period (no. of sampling dates)	No. of specimens	% *A. tomentosus*[a]
French's Canyon			
Willow	May–June1997 (7)	25	92.0
Willow	July–Sept.1997 (7)	57	45.6
Oak	July–Sept.1997 (7)	73	0.0
Cottonwood	July–Sept.1997 (7)	14	7.1
Cascade Park			
Willow	May–June1997 (5)	20	60.0
Willow	July–Sept.1997 (6)	123	69.1
Cottonwood	July–Sept.1997 (6)	56	8.9
Alder	July–Sept.1997 (6)	32	40.6
Aspen	July–Sept.1997 (6)	21	57.1

Nymphs were reared to the adult stage in laboratory for identification.

[a] No *A. whitei* were collected from these tree species; thus, percentage of sample composed of *A. antevolens* is equal to (100%–% *A. tomentosus*).

Table 5. Total numbers of overwintering bugs (with numbers per 10 traps included in parentheses) collected from overwintering traps placed in orchards

Species	Moxee 1996				Golf Course 1996	Moxee 1997		
	Pear [45]	Apple [35]	Peach [19]	Necatrine [19]	Pear [30]	Pear [54]	Apple [35]	Peach [30]
A. tomentosus	0	0	0	0	2 (0.7)	1 (0.2)	1 (0.3)	1 (0.3)
A. antevolens	4 (0.9)	0	0	0	1 (0.3)	21 (3.9)	2 (0.6)	1 (0.3)
D. brevis	167 (37.1)	46 (13.1)	23 (12.1)	17 (9.0)	7 (2.3)	77 (14.3)	23 (6.6)	14 (4.7)

Numbers in brackets associated with each plant species indicate total number of traps (bands + bundles) sampled for that plant species. Overall sex ratios (expressed as percentage of females) for each predator are (plant species combined): *A. tomentosus* (100%, $n = 5$ insects); *A. antevolens* (83%, $n = 29$); *D. brevis* (57%, $n = 374$). Other Anthocoridae recovered included 491 female *Orius tristicolor* (Moxee 1996: pear [32.7 per 10 traps], apple [22.6 per 10 traps], peach [76.3 per 10 traps], nectarine [46.8 per 10 traps]. Moxee 1997: pear [2.4 per 10 traps], apple [1.4 per 10 traps], peach [6.3 per 10 traps]), 3 female *Lyctocoris campestris* (Moxee pear), and 6 male *L. campestris* (Moxee pear).

important summer hosts (the latter species only for *A. whitei*). Movement onto alder coincided with a build-up in populations of an unidentified psyllid. Willow, oak, and cottonwood were heavily infested in the summer by a number of different soft-bodied arthropods, including lepidoptera larvae, aphids, thrips, mites, leafhoppers, and leaf miners. Aspen was colonized comparatively late in the summer (Table 2), apparently in response to infestation of this tree species by an unidentified aphid. Anthocorid densities on poplar at the England's site were very low until late in the season, when very large numbers of *A. antevolens* were collected in association with a gall-producing aphid.

Comparative Distribution of *A. tomentosus* and *A. antevolens* on Important Host Plant Species. *A. tomentosus* and *A. antevolens* differed noticeably in use of some tree species (Tables 3 and 4). At French's Canyon, >75% of insects in this genus collected from willow were *A. tomentosus*, whereas percentages on neighboring summer host plants (oak and cottonwood) were below 15% (Table 3). Similar trends were noted at Cascade Park, where *A. tomentosus* dominated on willow and *A. antevolens* dominated on cottonwood (Table 3). These patterns were seen to some extent for immatures as well (Table 4). Overall percentages of nymphs collected from willow were 60–68% *A. tomentosus.* Immatures of *A. tomentosus* were comparatively uncommon on cottonwood at both sites (Table 4). All 73 nymphs collected from oak were *A. antevolens.* Of the 190 adult *Anthocoris* spp. collected between May and August 1996 from the pear orchards at the golf course and Moxee, 89 (47%) were *A. tomentosus* and the remaining 53% were *A. antevolens.* Few anthocorids occurred in the orchard at the England's site because of chemical control of insect pests, but all three anthocorids (*A. tomentosus*, *A. antevolens*, *A. whitei*) were present at one time or another in the orchard (unpublished data).

Overwintering in Different Habitats. *A. antevolens* and *D. brevis* were considerably more abundant in the overwintering bands and bundles than were *A. tomentosus* and *A. whitei* (Tables 5–8). *D. brevis* was common in most habitats at all sites except Cascade Park; the species was especially abundant in the fruit trees at the Moxee orchard, where densities exceeded one per band in some habitats (Table 5). *A. antevolens* was extremely abundant in bands placed in cottonwood and poplar (exceeding 10 per band in 1997; Tables 6–7), both plant species apparently being important late-season sources of prey for this predator. *A. tomentosus* was at low densities at all sites and in all plant species. *A. whitei* was collected only from pear and bitterbrush, and only at the England's site (Table 6).

Three other anthocorids [*Orius tristicolor* (White), *Lyctocoris campestris* (F.), *Tetraphleps latipennis* Van Duzee], and one other species of *Deraeocoris* (*D. bakeri* Knight) were collected from bands (see footnotes to Tables 5–8). Of these species, *O. tristicolor* was easily the most abundant, particularly at the Moxee orchard site on peach (Table 5). *D. bakeri* was collected from bitterbrush and oak. This species was also occasionally collected on beat tray samples taken in bitterbrush during the late summer (unpublished data).

Table 6. Total numbers of overwintering bugs (with numbers per 10 traps included in parentheses) collected from overwintering traps placed in three commonly used shrub and tree species at England's orchard site

Species	1995		1996		1997		
	Pear [20]	Poplar [30]	Pear [21]	Poplar [12]	Pear [14]	Poplar [29]	Bitterbrush [54]
A. tomentosus	0	0	0	0	0	4 (1.4)	0
A. antevolens	1 (0.3)	86 (28.7)	0	3 (2.5)	0	411 (141.7)	0
A. whitei	0	0	2 (1.0)	0	1 (0.7)	0	51 (9.4)
D. brevis	(ND)	(ND)	7 (3.3)	6 (5.0)	4 (2.9)	56 (19.3)	13 (2.4)

ND, data not collected for this species in 1995–1996. Numbers in brackets associated with each plant species indicate total number of traps (bands + bundles) sampled for that plant species. Overall sex ratios (expressed as percentage of females) for each predator are (plant species combined): *A. tomentosus* (100%, $n = 4$ insects); *A. antevolens* (63%, $n = 501$); *A. whitei* (80%, $n = 54$); *D. brevis* (70%, $n = 86$). Other Anthocoridae and *Deraeocoris* sp. recovered included 2 female *Orius tristicolor* (bitterbrush), 2 female *D. bakeri* (bitterbrush), and 3 male *D. bakeri* (bitterbrush).

Table 7. Total numbers of overwintering bugs (with numbers per 10 traps included in parentheses) collected from overwintering traps placed in three commonly used tree species at French's Canyon site

Species	1996		1997		
	Willow [27]	Oak [23]	Willow [125]	Oak [46]	Cottonwood [25]
A. tomentosus	0	0	1 (0.1)	0	2 (0.8)
A. antevolens	0	2 (0.9)	53 (4.2)	11 (2.4)	426 (170.4)
D. brevis	2 (0.7)	4 (1.7)	2 (0.2)	12 (2.6)	6 (2.4)

Numbers in brackets associated with each plant species indicate total number of traps (bands + bundles) sampled for that plant species. Overall sex ratios (expressed as percentage of females) for each predator are (plant species combined): *A. tomentosus* (100%, $n = 3$); *A. antevolens* (70%, $n = 492$); *D. brevis* (77%, $n = 26$). Other Anthcoridae and *Deraeocoris* sp. recovered included 1 female *Orius tristicolor* (willow), 6 female *O. tristicolor* (oak), 2 female *O. tristicolor* (cottonwood), 9 female *Tetraphleps latipennis* (cottonwood), and 3 male *Deraeocoris bakeri* (oak).

Sex ratios for overwintering *Anthocoris* spp.and *D. brevis* were strongly to moderately female biased (see footnotes to Tables 5–8). All 504 *O. tristicolor* collected in overwintering traps were female.

Miscellaneous Anthocoridae and *Deraeocoris* spp. Collected. Several other Anthocoridae or *Deraeocoris* spp. were encountered incidentally in our samples (Table 9). The most common of these species was *O. tristicolor*, which we recorded from >25 species of woody or herbaceous plant species (Table 9). *Melanocoris nigricornis* Van Duzee and *Elatophilus pullus* Kelton & Anderson were fairly common on ponderosa pine at both the French's Canyon and Cascade Park sites. Two individuals of *M. nigricornis* were also collected from pear at the England's site; these observations probably are of incidental importance only, because this species apparently is restricted to coniferous trees for reproductive activities. *L. campestris* was recovered from overwintering bundles placed in the pear orchard at the Moxee site in fall of 1997 (Table 5), 1998 (unpublished data), and 1999 (unpublished data). The source of these overwintering insects is not known. *D. bakeri* was relatively common on bitterbrush late in the season at the England's site, and also was collected from bundles placed in this same location and plant species. Adults and immatures of an unidentified species of *Deraeocoris* (Table 9) were very common at French's Canyon occurring on oak. The species was never collected at any other site, nor was it observed anywhere except on oak.

Discussion

Although predatory Heteroptera are often considered to be generalized in feeding habits, it has become clear that many species are actually highly specialized (Ruberson and Coll 1998, Lattin 1999). Moreover, even closely related species may show wide differences in degree of specialization. Species of *Anthocoris* have been shown to differ substantially in prey preferences, or in growth and survival on a given prey species (Hill 1961, Anderson 1962c, Dempster 1963, Hodek 1993). European species of *Anthocoris* differ extensively in breadth of host plant use, as shown by the habits of highly specialized species such as *A. gallarumulmi* (De Geer) and *A. sarothamni* Douglas & Scott, in contrast to generalist species such as *A. nemorum* (L.) and *A. nemoralis* (F.) (Anderson 1962b, 1962c; Dempster 1963; Hill 1978). The current study suggests that *A. whitei*, *A. tomentosus*, and *A. antevolens* differed in prey preferences and degree of specialization. For example, adult *A. whitei* were collected from only two plant species, pear and bitterbrush; nymphs of this species were collected only from bitterbrush. Both plant species are hosts to specialized psyllids, which may have been the primary prey for this predator. Literature reports also suggest that *A. whitei* is closely associated with psyllid prey, including species associated with bitterbrush, greenleaf manzanita (*Arctostaphylos patula* E. Greene), Oregon tea (*Ceanothus sanguineus* Pursh), and pear (Westigard et al. 1968, Kelton 1978, Valenti et al. 1996; T.M.L., unpublished data).

In contrast to the specialized *A. whitei*, both *A. tomentosus* and *A. antevolens* appear to be fairly generalized in their feeding habits. Both predators were collected from plant species that were not populated by *A. whitei*, notably willow, poplar, cottonwood, oak, alder, and aspen. However, even for these two generalists, there were some conspicuous dissimilarities.

Table 8. Total numbers of overwintering bugs (with numbers per 10 traps included in parentheses) collected from overwintering traps placed in four commonly used tree species at Cascade Park site

Species	1996				1997			
	Willow [47]	Cottonwood [11]	Aspen [9]	Alder [10]	Willow [118]	Cottonwood [34]	Aspen [41]	Alder [39]
A. tomentosus	2 (0.4)	1 (0.9)	0	0	3 (0.3)	0	1 (0.2)	0
A. antevolens	1 (0.2)	2 (1.8)	12 (13.3)	0	1 (0.1)	29 (8.5)	7 (1.7)	4 (1.0)
D. brevis	1 (0.2)	0	0	0	0	2 (0.6)	2 (0.5)	2 (0.5)

Numbers in brackets associated with each plant species indicate total number of traps (bands + bundles) sampled for that plant species. Overall sex ratios (expressed as percentage of female) for each predator are (plant species combined): *A. tomentosus* (71%, $n = 7$ insects); *A. antevolens* (79%, $n = 56$); *D. brevis* (57%, $n = 7$). Other Anthocoridae recovered included 1 female *Orius tristicolor* from willow and 1 female *O. tristicolor* from alder.

Table 9. Miscellaneous Anthocoridae (other than *Anthocoris* spp.) and *Deraeocoris* spp. (other than *D. brevis*) collected during the study

Species[a]	Sampling location	Plant species
Anthocoridae		
Orius tristicolor	FC, CP, M, E	Numerous species[b] (Overwintering: several species[c])
Elatophilus pullus	FC, CP	Ponderosa pine[d]
Elatophilus sp[e]	FC	Ponderosa pine
Melanocoris nigricornis	FC, CP	Ponderosa pine[d]
	E	Pear
Xylocoris umbrinus Van Duzee	E	Bitterbrush
Tetraphleps latipennis	FC	Willow, Ponderosa pine (Overwintering: cottonwood[c])
T. feratis (Drake and Harris)	E	Bitterbrush
Lyctocoris campestris	M	(Overwintering: pear[c])
Deraeocoris spp.		
D. bakeri	E	Bitterbrush (Overwintering: bitterbrush[c])
D. fasciolus Knight	GC	Pear
Deraeocoris sp.[f]	FC	Oak[d]

FC, French's Canyon; CP, Cascade Park; M, Moxee orchard; E, England's orchard; GC, Golf Course orchard.

[a] Vouchers of all species except *X. umbrinus*, *T. feratis*, and *D. fasciolus* deposited with Washington State University. Specimens of remaining 3 species in collection of junior author.

[b] *Orius tristicolor* was recorded from peach, apple, nectarine, pear, plum, lupine, bitterbrush, big sage, thistle (*Cirsium*), chokecherry, mock orange, bramble, currant, rose, willow, oak, yarrow (*Achillea*), alfalfa (*Medicago*), baby's breath (*Gypsophila*), curly dock (*Rumex*), clover (*Melilotus*), hawthorn, mullein (*Verbascum*), alder, *Ceanothus* sp., cottonwood, and oceanspray.

[c] See Tables 5–8 for overwintering lists.

[d] Immatures collected from that plant species.

[e] Unidentified brachypterous specimen; in collection of junior author.

[f] Keyed to *D. fusifrons* Knight in Razafimahatratra (1981).

That is, certain plant species important to *A. antevolens* were either a very poor source of immature *A. tomentosus* (cottonwood; Table 4) or were apparently not used at all as a reproductive host by *A. tomentosus* (oak; Table 4). *A. antevolens* occasionally reached very high densities late in the season on poplar (Table 6), apparently in association with an abundant gall-producing aphid, whereas *A. tomentosus* was extremely rare on this tree. Literature reports also suggest that oak and poplar are important sources of prey for *A. antevolens* (Harper 1959, Anderson 1962a, Alleyne and Morrison 1974, Kelton 1978), but apparently not for *A. tomentosus* (see plant list for *A. tomentosus* in Kelton 1978). We also collected a few adults of *A. antevolens* from ponderosa pine (*P. ponderosa*), but never recorded *A. tomentosus* on this species. Lattin and Stanton (1992), in an exhaustive survey, recorded *A. antevolens* occurring on *Pinus contorta* Douglas, but made no mention of *A. tomentosus.* Finally, both adult and immature *D. brevis* were collected from more plant species than any of the anthocorids, suggesting that this mirid is more of a generalist than any of the anthocorid bugs. Literature reports also suggest that this species occurs on a wide range of plant species (Westigard 1973, Kelton 1982). One practical consideration concerning the dietary ranges of these species is that *D. brevis* is likely to be a much more important biocontrol agent in apple orchards than any of the three *Anthocoris* spp. studied here. *D. brevis* was often extremely abundant in apple orchards, particularly when aphid outbreaks occurred, whereas we recovered almost no specimens of *Anthocoris* spp. from apple, despite regular occurrence of these insects in neighboring pear orchards.

Both *A. tomentosus* and *A. antevolens* appear to be active very early in the season, congregating on willow catkins beginning at least in March. None of the other tree or shrub species in the sampling areas showed much development at that time of the year, which may partially explain the early-season distribution. An unidentified psyllid (*Cacopsylla* sp.) was quite active on willow catkins very early in spring and may have been an important prey item, although catkins are also host to numerous small bodied-arthropods other than psyllids (Anderson 1962b). Male *Salix* spp. are also heavily laden with pollen in early spring, but it is unclear whether pollen is an important source of food for *Anthocoris* spp. (Anderson 1962b). The willow-inhabiting psyllid is univoltine and disappeared from willow in June (unpublished data), and it is likely that decreased availability of this prey species prompted some of the movement onto summer hosts by *A. tomentosus* and *A. antevolens* (Fig. 3; Table 2). For *A. whitei* occurring on bitterbrush, reddish psyllid nymphs were seen to be present as early as late February, and it is probable that these were important early-season prey for this predator. Unlike the univoltine psyllid occurring on willow, the psyllid that occurs on bitterbrush is multivoltine and was present (often at high densities) throughout the growing season.

The seasonal expansion in host plant use noted for *A. tomentosus* and *A. antevolens* (Table 2) is common in this genus. Like *A. tomentosus* and *A. antevolens*, several European species of *Anthocoris* use *Salix* extensively just after emergence from overwintering quarters, including *A. confusus* Reuter (Hill 1965), *A. nemorum* (Hill 1957, Anderson 1962b, Collyer 1967), and *A. nemoralis* (Anderson 1962b). Migration to other plant species occurs apparently in conjunction with declining prey on willows (Hill 1957, Anderson 1962b), perhaps especially in response to declining populations of (univoltine) psyllids (Anderson 1962b). Summer host plants for the European species include a diverse number of woody and (to a lesser extent) herbaceous species supporting small soft-bodied prey such as aphids, mites, and thrips (Hill 1957, 1978; Anderson 1962b).

The three species of *Anthocoris* were collected primarily from woody plant species. Only very rarely were immature *Anthocoris* spp. collected while sampling herbaceous vegetation. The few immatures that were collected from understory vegetation were taken from plants growing just beneath trees that were populated by *Anthocoris* spp. Some European species of *Anthocoris* commonly are reproductive on herbaceous

species (most notably *A. nemorum;* Southwood and Scudder 1956, Collyer 1967, Perrin 1975, Smith 1976), although most species appear to prefer trees or shrubs (Hill 1957, 1961, 1978; Anderson 1962b; reviewed in Lattin 1999).

Of the three species of *Anthocoris*, *A. antevolens* was the most abundant and the most broadly distributed across plant species and sites in the overwintering samples (Tables 5–8). This species was particularly common in poplar and cottonwood, tree species that appear to be important late-season sources of prey in the study areas. Again, as with the summer samples, *D. brevis* was distributed more broadly than any of the three *Anthocoris* spp., particularly in the orchards (Table 5). *O. tristicolor* was very abundant overwintering in both stone and pome fruit trees at the Moxee site, and was especially common in peach (see footnote to Table 5). This result is similar to observations made by Tamaki and Halfhill (1968) who suggested that *O. tristicolor* was abundant in bands placed around peach trees because of high densities of spider mites in peach orchards. Overwintering sex ratios for *Anthocoris* spp. were biased in favor of females, as reported also elsewhere (Horton et al. 1998). No males of *O. tristicolor* were recovered from any of the overwintering samples (Tables 5–8).

Lastly, it still is not completely clear how non-orchard habitats and sources of prey outside of the orchard affect biological control by these predators in orchards. Reports indicate that *D. brevis*, *A. tomentosus*, and *A. antevolens* cause substantial mortality of pests in pear orchards if the predators are present in sufficient numbers (Madsen 1961, Madsen et al. 1963, Madsen and Wong 1964, Nickel et al. 1965, McMullen and Jong 1967, Shimizu 1967, Westigard et al. 1968). However, there is considerable variation among orchards and years in abundance of these species in orchards, and this variation is difficult to explain. In the western United States, *D. brevis* appears to be important in both apple (Carroll and Hoyt 1984; the current study) and pear orchards (Westigard et al. 1968), whereas *A. tomentosus*, *A. whitei*, and *A. antevolens* occur in pear orchards (Madsen 1961, Nickel et al. 1965, Westigard et al. 1968; the current study) but are uncommon in apple orchards (Carroll and Hoyt 1984; the current study). Other species of *Anthocoris* in other growing regions may be more abundant on apple than observed in our current study. Lord (1949) reports that *A. musculus* (Say) is one of the first predators in eastern Canada to colonize apple orchards in fall after insecticide applications. In Europe, several species of *Anthocoris*, including *A. confusus*, *A. nemoralis*, and *A. nemorum*, are abundant in apple orchards (Collyer 1953, Glen 1975, Austreng and Sømme 1980, Solomon 1982).

We conclude from the current study that non-orchard habitats support large populations of these important predators. There is increasing interest shown by growers and pest control advisers in managing habitat to enhance biological control in crops (Pickett and Bugg 1998). Pear growers in the Pacific Northwest could potentially benefit by making use of non-orchard sources of predators, perhaps by encouraging growth of native plants in the vicinity of their orchards or by use of the appropriate type of hedgerows or windbreaks. For instance, both willow and poplar are planted as windbreaks in North American and European tree fruit growing regions. Both taxa may support high densities of anthocorid predators, either in early spring or in late fall, and thus may be potential sources of biological control in orchards (Fields and Beirne 1973, Solomon 1982).

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